Affordable Desalination Collaboration
Quarterly Technical Progress Report
Covering Period July 1, 2009 to September 31, 2009

TWDB Contract No. 0804830845

CONTRACTOR – Affordable Desalination Collaboration
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RESEARCH PROJECT – Optimizing Brackish Water Reverse Osmosis for Affordable Desalination

BOARD APPROVAL DATE – April 21, 2008

CONTRACT INITIATION DATE – September 15, 2008

STUDY COMPLETION DATE – June 13, 2011

FINAL REPORT DEADLINE – June 13, 2011

TOTAL STUDY COSTS – $ 1,356,683

BOARD SHARE OF THE TOTAL STUDY COSTS- the lesser of $496,783 or the total combined amount corresponding to the percentages of TWDB funding for each of the tasks shown in exhibit C.

LOCAL SHARE OF THE TOTAL STUDY COSTS - $859,900 in cash and $0.00 in-kind services or the amount remaining after the total combined amount corresponding to the percentages of TWDB funding for each of the tasks shown in Exhibit C.

PAYMENT SUBMISSION SCHEDULE - Monthly

Date Submitted: 11-25-09

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Signed, Reviewed by designated representative

1. **Project Objective:** The objectives of the Affordable Desalination Collaboration (ADC) are to demonstrate affordable, reliable and environmentally responsible reverse osmosis desalination technologies and to provide a platform by which cutting edge technologies can be tested and measured for their ability to reduce the overall cost of the reverse osmosis (RO) treatment process

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2. **Project Description / Background:** A key challenge facing inland desalination today is to develop a new generation of reverse osmosis plants that deliver high-quality, fresh water at reduced economic and environmental cost. Two key areas of focus that will help achieve these goals are the energy consumption and the achievable RO recoveries of inland brackish water systems.

   The ADC was formed in 2004 to fund and execute the first part (ADC I), which became a multiple phase project funded under the California Department of Water Resources Proposition 50 program. Under the program the ADC built and operated a demonstration plant at the United States Navy's Seawater Desalination Test Facility in Pt. Hueneme, California. The ADC achieved remarkable results by desalinating seawater at energy levels between 6.0-6.9 kWh/kgal (1960-2250 kWh/acre-ft).

   This project funded by the Texas Water Development Board (TWDB) and titled "Optimizing Brackish Water Reverse Osmosis for Affordable Desalination" will pursue the following demonstration, and development tasks.

   1. Test and demonstrate state of the art isobaric energy recovery technology in an optimized brackish water design. The ADC expects to achieve 15-30% energy savings over traditional brackish water systems even where energy recovery turbines are applied.
   2. Develop and demonstrate new process designs that are possible as a result of the isobaric energy recovery technologies. As a natural result of the pressure exchanger (PX) technology in particular, there are new kinds of flow schemes that can improve the performance of higher recovery brackish water systems. We will use the ADC pilot system to test and demonstrate these new flow schemes in order to push the recoveries beyond what has been traditionally achievable.

   The ADC represents a unique collaboration leading government agencies, municipalities, RO manufacturers, consultants and professionals that are working together to improve the designs and technology applied in state of the art desalination systems. Our demonstration plant, processes and personnel have been pre-qualified and proven to meet project goals and produce valid data on the operation of desalination systems. Our outreach and information sharing efforts have been extensive and reached a wide range of audiences. In short, the ADC is an established leader in the field of reverse osmosis technology and we are uniquely qualified to conduct the proposed project and disseminate the results to the appropriate audiences.

3. **Progress and Status:**

   To date we have completed the first three tasks of our contract including gaining agreements to operate our system at the El Paso Water Utilities' Kay Bailey Hutchison Desalination Plant and reconfiguring our system from a seawater design to an optimized brackish water design. We have reached a preliminary agreement with El Paso Water Utilities to operate our system at the Kay Bailey facility and final agreement is pending review and signature. We have also completed the draft test protocol (attached).

4. **Percent Complete of Total Project:** ~ 22 %

5. **Deliverables:**

Trade Show/Conference/Publication	Date(s)	Author(s)	Presenter	TWDB Submittal
Joint ADC-AMTA workshop, Annual Conference, Austin, Texas	July 2009	n/a	Various	Q2-09
Innovative Designs to Be Tested in ADC	Sept/Nov 2007	John P. MacHarg	n/a	Q2-09

6. **Expenditures:** See next pag

ADC-TWDB Expenditure Table

EXPENSE BUDGET				SEPTEMBER INVOICE			BALANCE		
Category	**Applicant**	**TWDB**	**Total**	**Applicant**	**TWDB**	**Total**	**Applicant**	**TWDB**	**Total**
Salaries, wages	$0	$133,115	$133,115	$0	$18,000	$18,000	$0	$115,115	$115,115
Fringe benefits	$0	$39,935	$39,935	$0	$5,400	$5,400	$0	$34,535	$34,535
Supplies	$0	$13,500	$13,500	$0	$0	$0	$0	$13,500	$13,500
Equipments	$411,800	$6,000	$417,800	$0	$0	$0	$411,800	$6,000	$417,800
Consulting services	$14,500	$17,000	$31,500	$0	$0	$0	$14,500	$17,000	$31,500
Travel	$0	$15,000	$15,000	$0	$1,195	$1,195	$0	$13,805	$13,805
Planning/design/engineering	$9,100	$7,852	$16,952	$0	$2,835	$2,835	$9,100	$5,017	$14,117
Materials/Installation/Implementation	$38,000	$36,440	$74,440	$6,956	$36,440	$43,396	$31,044	$0	$31,044
Implementation verification	$10,000	$5,500	$15,500	$0	$0	$0	$10,000	$5,500	$15,500
project legal/License/Insurance Fees	$0	$13,500	$13,500	$0	$0	$0	$0	$13,500	$13,500
Other (Membership fees and other operating cash)	$311,000	$0	$311,000	$0	$0	$0	$311,000	$0	$311,000
Operation, monitoring and assesment	$0	$105,942	$105,942	$0	$0	$0	$0	$105,942	$105,942
Report preparation	$2,000	$2,500	$4,500	$0	$0	$0	$2,000	$2,500	$4,500
Outreach and information sharing	$63,500	$0	$63,500	$0	$0	$0	$63,500	$0	$63,500
Overhead (8%)	$0	$100,495	$100,495	$0	$5,110	$5,110	$0	$95,385	$95,385
			$0	$0	$0	$0	$0	$0	$0
			$0	$0	$0	$0	$0	$0	$0
TOTALS	**$859,900**	**$496,779**	**$1,356,679**	**$6,956**	**$68,980**	**$75,936**	**$852,944**	**$427,799**	**$1,280,743**

7. **Schedule Status:** We are currently on schedule.

8. **Plans for Next Quarter:** During Q4-09 we plan to install and begin to operate our demonstration plant at the El Paso Water Utilities' Kay Bailey Hutchison Desalination Plant.

9. **Attachments:** n/a

All quarterly reports should be publicly disclosable and not contain confidential, proprietary or business sensitive information.

Task and % Complete Progress Table

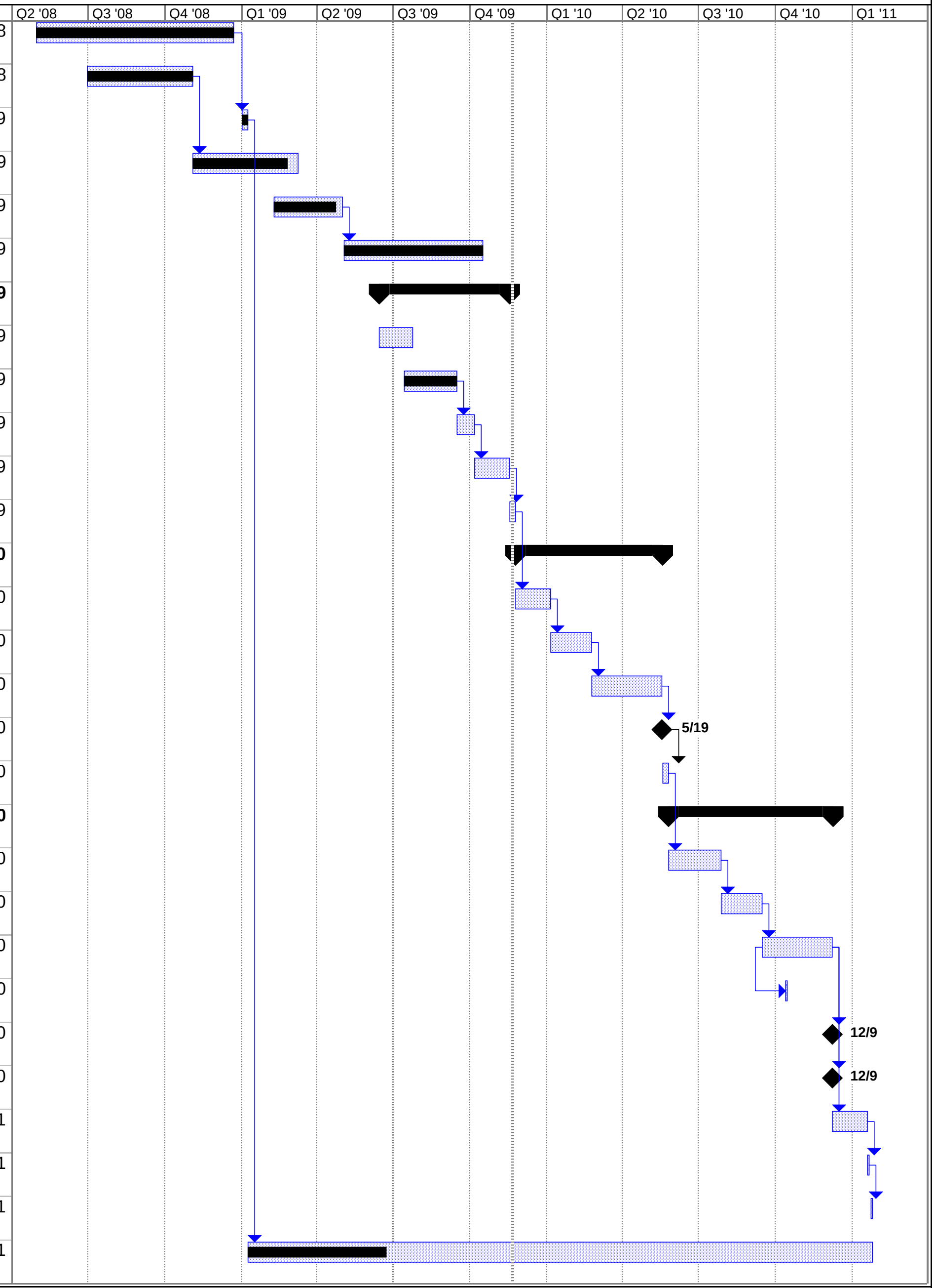
Agreement Number 0804830845	Starting Date: 1-7-09	Completion Date: 6-13-11	Quarter-Year Q2 & Q3 2009	Report Number 1	PERCENT OF
Grantee Agency Name: Affordable Desalination Collaboration		% Time Elapsed 23%	Total Grant Funds used $ 68,980	Grant funds this Qtr $ 68,980	
Name of Project: Optimizing Brackish Water Reverse Osmosis for Affordable Desalination					

TASKS	2009 Qtr 1	2009 Qtr 2	2009 Qtr 3	2009 Qtr 4	2010 Qtr 1	2010 Qtr 2	Project	Task Complete Last Report	Task Complete This Report	Project Complete
Task 1: Finalize Agreements with local test site/agency							7%	0%	90%	6%
Task 2: Attain permits							7%	0%	100%	7%
Task 3: Reconfigure system for interstage optimized design							13%	0%	70%	9%
Task 4: Decommission equipment at Port Hueneme							8%	0%	0%	0%
Task 5: Install and commission equipment on site.							8%	0%	0%	0%
Task 6: Execute multiple point optimization search							10%	0%	0%	0%
Task 7: Run 2 month demo at most affordable point							17%	0%	0%	0%
Task 8: Execute unbalanced multiple point optimization search							10%	0%	0%	0%
Task 9: Run 2 month demo at unbalanced most affordable point							17%	0%	0%	0%
Task 10: Member/general workshop							3%	0%	0%	0%
Show Progress by Use of Bar Chart — **Scheduled =** / **Completed =**							100%			22%

Schedule

Project Schedule Gant Chart.

ID	Task Name	Duration	Start	Finish
1	TWDB Agreement development	168 days	Thu 5/1/08	Mon 12/22/08
2	Develop tentative agreement with local water agency/test site	90 days	Tue 7/1/08	Mon 11/3/08
3	Final TWDB agreement signed / Project Begins	5 days	Fri 1/2/09	Thu 1/8/09
4	Detailed negotiations and planning with local agency/test site	90 days	Tue 11/4/08	Mon 3/9/09
5	Develop detailed test protocol	60 days	Mon 2/9/09	Fri 5/1/09
6	Permitting/agreements	120 days	Mon 5/4/09	Fri 10/16/09
7	**Install and commission Equipment on site**	**112 days**	**Mon 6/15/09**	**Tue 11/17/09**
8	Prepare site, wells, piping for ADC equipment	30 days	Mon 6/15/09	Fri 7/24/09
9	Decomission and reconfigure equipment at Port Hueneme	45 days	Wed 7/15/09	Tue 9/15/09
10	Ship equipment to Texas	15 days	Wed 9/16/09	Tue 10/6/09
11	Install and commission equipment on site	30 days	Wed 10/7/09	Tue 11/17/09
12	Submit project update report to TWDB	5 days	Wed 11/18/09	Tue 11/24/09
13	**High Recovery Process Design Testing**	**126 days**	**Wed 11/25/09**	**Wed 5/19/10**
14	Flush and base line membranes	30 days	Wed 11/25/09	Tue 1/5/10
15	Execute unbalance test protocol @ 18 points	35 days	Wed 1/6/10	Tue 2/23/10
16	PX unbalanced most affordable point (24/7 for 2 months)	60 days	Wed 2/24/10	Tue 5/18/10
17	Complete Unbalanced PX testing	1 day	Wed 5/19/10	Wed 5/19/10
18	Submit project update report to TWDB	5 days	Thu 5/20/10	Wed 5/26/10
19	**Optimized Isobaric Energy Recovery Demonstration**	**141 days?**	**Thu 5/27/10**	**Thu 12/9/10**
20	Reconfigure system for Interstage-PX hybrid design	45 days	Thu 5/27/10	Wed 7/28/10
21	18 point optimization search	35 days	Thu 7/29/10	Wed 9/15/10
22	Most affordable point (24/7 for 2 months)	60 days	Thu 9/16/10	Wed 12/8/10
23	Clean membranes	2 days	Thu 10/14/10	Fri 10/15/10
24	Complete Interstage-PX Hybrid testing	1 day?	Thu 12/9/10	Thu 12/9/10
25	Complete testing	1 day	Thu 12/9/10	Thu 12/9/10
26	Write final report	30 days	Thu 12/9/10	Wed 1/19/11
27	Submit final report, billing, conclude project	2 days	Thu 1/20/11	Fri 1/21/11
28	Member/general workshop and publish results	2 days	Mon 1/24/11	Tue 1/25/11
29	Project Duration	533 days	Fri 1/9/09	Tue 1/25/11



Project: ADC TWDB Brackish Demons
Date: Fri 11/20/09

Task	Summary	Rolled Up Progress	Project Summary
Progress	Rolled Up Task	Split	Group By Summary
Milestone	Rolled Up Milestone	External Tasks	Deadline

Attachments

1. Test Protocol

AFFORDABLE DESALINATION COLLABORATION

TEXAS WATER DEVELOPMENT BOARD

BRACKISH WATER RO DEMONSTRATION STUDY

LOCATION: EL PASO DESALINATION PLANT

DRAFT - VALIDATION PROTOCOL

ADC Demonstration Pilot System

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ADC-TWDB BRACKISH WATER RO DEMONSTRATION STUDY

1.0 INTRODUCTION

1.1 Background

The Affordable Desalination Collaboration (ADC) is a California non - profit organization comprised of state and federal government agencies, water districts, and industry leaders working together to demonstrate seawater desalination as a reliable, affordable, an environmentally sound source of potable water. The original objective of the ADC was to design, build and test a scalable SWRO plant using commercially available technology that can demonstrate efficient energy consumption. The ADC's demonstration scale SWRO plant (rated seawater capacity of 48,000 gpd to 75,600 gpd) was tested at the U.S. Navy's Desalination Research Center, located in Port Hueneme, California, and operated from May 2005 through July 2009. Key achievements of our initial seawater testing included:

- Demonstrating that SWRO is a viable water supply alternative for Southern California, as shown in Figure 1.1.
- Setting a world record low SWRO process energy consumption of 6.0 kWh/kgal of permeate produced.
- Test and demonstrate 7 membrane models from four manufacturers providing performance comparison under similar feed water conditions.
- Test and demonstrate Dow Filmtec's "hybrid membrane" design, by staging membranes of various performance in a single seven element vessel
- Test and demonstrate Dow Filmtec's high boron rejection membrane for seawater

- Demonstrate new process design configurations to achieve higher system recoveries in seawater (i.e., over 50%)
- Test and demonstrate the performance of GE/Zenon ZeeWeed® 1000 ultrafiltration (UF) membrane technology as a reliable method of pretreatment for SWRO systems for feed water conditions at the Port Hueneme Test Facility.

By testing and demonstrating these new technologies and designs and sharing the results, the ADC has been able to provide information to SWRO designers and industry stake holders that seawater desalination is an affordable, viable and reliable source of potable water for the future. The ADC website: www.affordabledesal.com details the goals, previous publications and information related to the ADC.

1.2 TWDB-ADC Demonstration Study Objectives

The objectives of this Texas Water Development Board Brackish (TWDB) Ground Water Demonstration Projects are as follows:

1. Develop and demonstrate new process designs that are possible as a result of the isobaric energy recovery technologies. As a natural result of the pressure exchanger (PX) technology in particular, there are new kinds of flow schemes that can improve the performance of higher recovery brackish water systems. We will use the ADC pilot system to test and demonstrate these new flow schemes in order to push the recoveries beyond what has been traditionally achievable.
2. Test and demonstrate state of the art isobaric energy recovery technology in an optimized brackish water design. The ADC expects to achieve 15-30% energy savings over traditional brackish water systems even where energy recovery turbines are applied.

The ADC will operate at the El Paso Brackish water Desalination facility and use the same feed water as the full scale plant. In so far as possible, the pilot system design will mimic the full scale plant so that comparisons may be made between the pilot system performance and the full scale plant performance.

While evaluating these brackish water process alternatives, it is important that potable water quality meets primary and secondary standards. Potable water quality goals for this ADC TWDB study are summarized in Table 1.2.

Table 1.2 Demonstration Scale Test Potable Water Quality Goals
Brackish RO Demonstration Study
Affordable Desalination Collaboration Part II

Parameter	Unit	Value	Basis
TDS	mg/L	< 500	Federal Secondary Standard
Chloride	mg/L	< 250	Federal Secondary Standard

2.0 VALIDATION PROTOCOL

This section describes the materials and methods used to validate that the following process design concepts and their potential to reduce either or both capital costs or energy consumption while meeting potable water quality goals.

- Optimized brackish water design with isobaric energy recovery
- Higher recovery operation through isobaric brine recirculation

2.1 Demonstration Scale Brackish RO Equipment

Criteria used to size the demonstration scale Brackish RO and UF Pretreatment equipment are presented in Table 2.1. A process flow diagrams are presented in Figures 2.1, 2.2, and 2.3.

Table 2.1 BWRO Demonstration Scale Test Equipment Criteria
Brackish water RO Demonstration Study
ADC-TWDB Brackish Water Demonstration Project

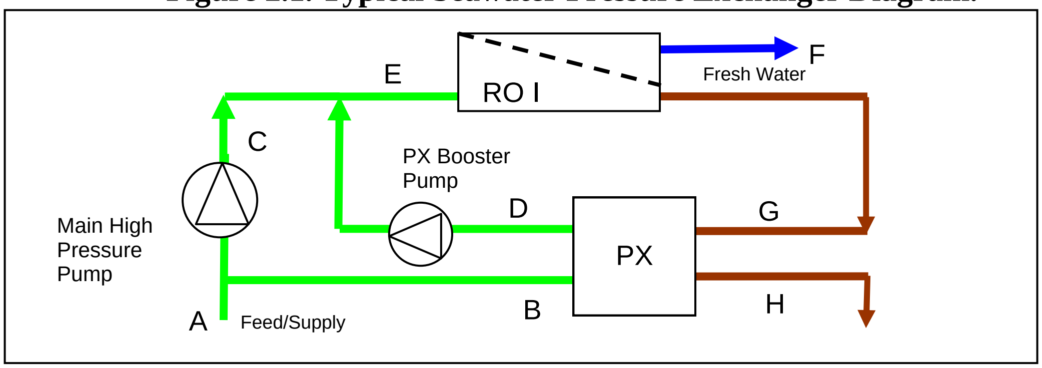
Parameter	Unit	Value
Feed, Flush, Cleaning Pump		
Manufacture/Model		AMPCO, ZC2 2.5x2
Duty Range	gpm @ ft H_2O	170gpm @ 80 ft TDH
Media Filter		
Manufacturer		ALAMO
Quantity	No.	2
Diameter	Inch	48
Height	Inch	72
Loading Rate	gpm/ft^2	3 to 6
Cartridge Filter		
Manufacturer/Model		Eden Excel, 88EFCT4-4C150
Quantity	No.	22
String Wound Cartridge Specs		#XL1-EP050-PLC40, 5 micron
Pressure Vessels		
Manufacturer/Model		Codeline, 80A100-7
Quantity	No.	3
No. of Membrane Elements per Vessel	No.	7
Membrane Element		

Table 2.1	**BWRO Demonstration Scale Test Equipment Criteria Brackish water RO Demonstration Study ADC-TWDB Brackish Water Demonstration Project**		
	Parameter	**Unit**	**Value**
	Manufacturers/ Models		Hydranautics ESPA1-7
	Quantity	No.	21
	Diameter	inch	8
	Surface Area	ft^2	400
	Total Membrane Area (A_{SYS})	ft^2	8400
High Pressure Pump			
	High Pressure Feed Pump Type		Positive Displacement
	Manufacturer		Danfoss
	Model		2 x APP-10.2
	Driver		VFD
	High Pressure Pump flow	gpm	40-90 (7-15 gfd)
	High Pressure Pump TDH	ft H_2O (psi)	349 to 2698 (150 to 1160)
PX Booster Pump			
	PX Booster Pump Type		Multi-stage Centrifugal
	Manufacturer		Energy Recovery, Inc.
	Model		HP-8504
	Driver		VFD
	PX Booster Pump TDH		70 to 115 (30 to 50)
Energy Recovery			
	Energy Recovery Devise Type		Pressure Exchanger
	Manufacturer		Energy Recovery, Inc.
	Model		PX-70S SW / PX-?? BW
	Quantity	No.	2
Notes:			

2.1.1 Optimized Isobaric Energy Recovery Demonstration

An isobaric energy recovery system utilizes the principle of positive displacement to pressurize filtered feed water by direct contact with the high-pressure concentrate (waste) stream or reject from an RO system. Within a pressure exchanger (PX) pressure transfer occurs in the longitudinal ducts of a ceramic rotor that spins inside a ceramic sleeve. The rotor-sleeve assembly is held between two ceramic end covers. At any given instant, half of the ducts are exposed to the high pressure fluid side and half the ducts are exposed to the low pressure fluid side. Figure 2.1 shows the flow path of a typical seawater reverse osmosis (SWRO) PX system. The concentrate from the RO membranes (G) passes through the PX, where its pressure is transferred directly to a portion of the incoming feed water at up to 97% efficiency. This pressurized feed water stream (D), which is approximately equal in volume and pressure to the reject stream, passes through a PX auxiliary pump (not the main high-pressure pump) to add the small amount of pressure lost due to the differential pressure across the membranes and to friction in the associated piping and the PX. The PX booster pump drives the flow through the high-pressure side (G and D) of the PX. Fully pressurized feed water then merges with the main feed water line of the RO system after the main high-pressure pump. In an RO-PX system, the main pump is sized to equal the RO permeate flow plus a small amount of rotor lubrication flow, not the full RO feed flow. Therefore, the PX significantly reduces flow through the main pump. This point is significant because a reduction in the size of the main pump results in lower power consumption and operating costs.

Figure 2.1. Typical Seawater Pressure Exchanger Diagram.



The RO-PX system requires a booster pump to make up the small amount of pressure losses through the membranes, PX, and the associated piping circuit. In the standard single stage seawater system this pump is applied at the outlet of the PX. However, in a 2 stage brackish water system the PX booster pump can serve 2 purposes by being installed in between stages 1 and 2 as shown in Figure 2-2. In this configuration the PX booster pump also acts as an interstage booster pump helping to reduce the required pressure from the main high pressure feed pump, by balancing the flux between the 1st and 2nd stages

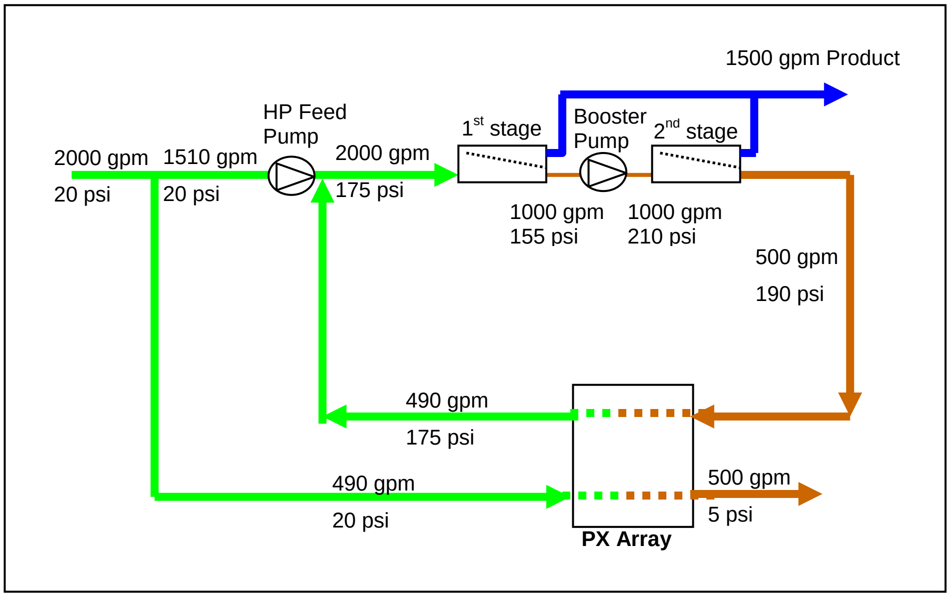


Figure 2-2. Example Interstage Booster PX Design @ 75% RO Recovery

The example in figure 2-2 (see Appendix A for detail P&ID) shows that while the PX booster is supplying the energy to drive the water around the PX circuit it is also conveniently providing 55 psi of interstage boost pressure. In addition to improving the flux balance, it also results in significant savings by both the PX reducing the main HP pump size and the lower 1st stage feed pressure inherent to an interstage booster design. Table 1 shows the PX power savings verses a standard interstage booster design.

Table 2-2. PX Savings in Interstage Booster system

	Std	ERI
Feed pump efficiency	83%	83%
Feed pump motor efficiency	94%	94%
Feed pump power, kW	172.9	130.3
Booster pump efficiency	80%	80%
Booster pump motor efficiency	94%	94%
Booster pump power, kW	23.2	31.8
RO Feed Pressure, PSI	175	175
RO Recovery, %	75%	75%
KWh/kgal	**2.19**	**1.82**
17% savings yields $17,500/year @ $0.06/kWh		

In conclusion, an optimally designed brackish water PX system can provide many benefits including energy savings and flux balance. These concepts could save operators of brackish water systems as much 10-30% of the operating energy compared to traditional systems while simultaneously improving the performance of the RO membranes.

2.1.1.1 - Procedure for testing Brine Recirculation Process

Demonstration scale tests of the Optimized Isobaric Energy Recovery system will occur over an approximate 6 month period. As presented in Table 2-3, each phase of testing consists of the following:

- Two weeks (weeks 1-2) of “ripening” at a typical flux and recovery rate. This “ripening” period has been included based upon past experience operating new membranes. Experience has indicated that approximately two and one half weeks are required before some new membrane’s performance (e.g., pressure and salt rejection) reaches a steady state condition. It is possible that pre-ripened membranes will be used in this test and this period may be shortened or omitted accordingly.
- Four weeks (weeks 3-6) of testing at different system flux and RO recovery points. Each flux and recovery point will be operated for 1 day to obtain the approximate energy and water quality performance at a given point.
- 2 month demonstration at a single flux and recovery point.

Tables 2-3 indicates the desired flux and recovery that will be set for this test. The applicable equations are as follows:

$$R = \frac{Q_{P-SYS}}{Q_{F-SYS}} * 100$$ **Equation 2.4**

$$Q_{F-SYS} = Q_{P-SYS} + Q_{REJECT}$$ **Equation 2.5**

$Q_{P\text{- HP-out}}$ $$Q_{PXPump} = Q_{REJECT} + 1.5 gpm\_leakage$$ **Equation 2.6**

$$Q_{P-SYS} = Q_{F-HPPump} - 1.5 gpm\_leakage$$ **Equation 2.7**

Where:
R = Recovery, %
$Q_{F\text{-SYS}}$ = RO system feed flow, gpm
$Q_{F\text{-HP Pump}}$ = High pressure positive displacement pump flow, gpm
$Q_{PX\text{-HP-out}}$ = PX High Pressure Outlet, gpm

Q_{Reject} = RO membrane reject flow, gpm

Between each system flux and recovery matrix, the original/ripening flux and recovery (i.e., the flux and recovery tested during weeks 1-2) will be retested to confirm membrane performance at baseline conditions.

Approximately 8 weeks of operating at the RO-System recovery point determined, ***through testing***, to 1) meet water quality goals for TDS and 2) results in the most affordable operation, as determined by a net present value analysis, or 3) and operating point that best matches the current operating conditions of full scale El Paso plant.

The data gathered from these tests shall be used to develop graphs that show the power consumption rate and water quality that can be achieved at each condition. Power consumption rate shall be measured to include the following electrical loads:

- High Pressure RO Pump (P2)

- PX Booster Pump (P3)

The following will not be included in the power consumption rate measurements

- Intake Lift Pump (P1)
- Chemical Metering Pumps
- Instrumentation and Controls
- Product water pumping
- Pretreatment pumping

While the intake lift pump may provide suction side pressure to the High Pressure Positive Displacement pump, thereby reducing the overall TDH, it will not be included in the power monitoring. For the affordability analysis, an intake pump's horsepower will be assumed based upon flow and overall lift TDH of 200 ft of H_2O.

Table 2-3 **Schedule of Testing Conditions**
Optimized Isobaric Energy Recovery Demonstration
ADC TWDB Desalination Demonstration Project

Parameter	**1-2 Weeks Ripening**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**
Membrane sq-ft	400				Base Line				Base Line
Flux, gfd	14.9	12	12	12	14.9	14.9	14.9	14.9	14.9
RO recovery	80.0%	75.0%	80.0%	85.0%	80.0%	75.0%	80.0%	85.0%	80.0%
System Recovery	80.0%	75.0%	80.0%	85.0%	80.0%	75.0%	80.0%	85.0%	80.0%
High Pressure RO Pump ($Q_{F\text{-}HP\ Pump}$), gpm	88.4	71.5	71.5	71.5	88.4	88.4	88.4	88.4	88.4
PX HP Outlet, ($Q_{PX\text{-}HP\text{-}Out}$), gpm	20.2	21.8	16.0	10.9	20.2	27.5	20.2	13.8	20.2
Permeate ($Q_{P\text{-}SYS}$), gpm	86.9	70.0	70.0	70.0	86.9	86.9	86.9	86.9	86.9
PX Low Pressure Inlet, gpm	20.2	21.8	16.0	10.9	20.2	27.5	20.2	13.8	20.2
Concentrate, gpm	21.7	23.3	17.5	12.4	21.7	29.0	21.7	15.3	21.7

				Base Line	
	Day 9	**Day 10**	**Day 11**	**Day 12**	**2 Month Demo Point**
Flux, gfd	16	16	16	14.9	TBD
RO recovery	75.0%	80.0%	85.0%	80.0%	TBD
System Recovery	75.0%	80.0%	85.0%	80.0%	TBD
High Pressure RO Pump ($Q_{F\text{-}HP\ Pump}$), gpm	94.8	94.8	94.8	88.4	TBD
PX HP Outlet, ($Q_{PX\text{-}HP\text{-}Out}$), gpm	29.6	21.8	15.0	20.2	TBD
Permeate ($Q_{P\text{-}SYS}$), gpm	93.3	93.3	93.3	86.9	TBD
PX Low Pressure Inlet, gpm	29.6	21.8	15.0	20.2	TBD
Concentrate, gpm	31.1	23.3	16.5	21.7	TBD

Notes:

1. Maximum system pressure is 600 psi. If any point exceeds 600 psi system will shutdown and point will need to be skipped.
2. Flows assume 400 sq-ft membrane
3. $Q_{F\text{-}HP\ Pump}$ = High pressure positive displacement pump flow = Product flow +1.5 gpm (PX leakage).
4. $Q_{PX\text{-}HP\text{-}Out}$ = PX booster pump flow= Concentrate flow gpm - 1.5 gpm (PX leakage).
5. $Q_{P\text{-}SYS}$ = SWRO system permeate flow.

2.1.2 Brine Recirculation Process for Higher Recovery in Single Stage Array

The brine recirculation process is achieved through unbalancing the flows through an isobaric energy recovery device. As a natural result of isobaric energy recovery systems there are new kinds of flow schemes that may improve the performance of higher recovery seawater and brackish water systems. One example is shown in Figure 2-3 below where a PX is intentionally unbalanced yielding an overall system recovery (F divided by A) of 85% and 2000 tds feed water, but the membrane recovery (F divided by E) is at 65% and 4,886 tds feed water.

Figure 2-3 The Unbalanced Pressure Exchanger Diagram Single Stage Array

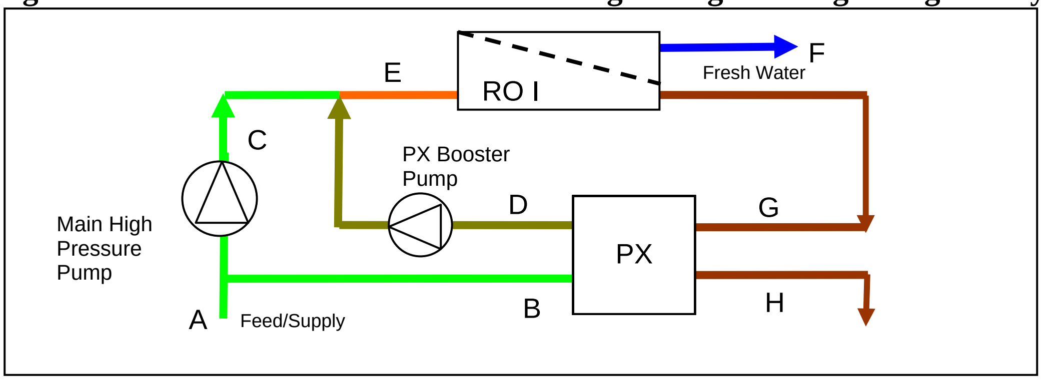


Table 2-4 Unbalanced PX 65/85% Recovery Projection Single Stage Array

		A	B	C	D	E	F	G	H
Flow	gpm	1774	250	1524	775	2299	1500	799	274
	gpd	2,554,560	360,000	2,194,560	1,116,000	3,310,560	2,160,000	1,150,560	394,560
Pressure	PSI	25	25	241	221	241	5	231	10
Quality	mg/l TDS	2,000	2,000	2,000	10,563	4,886	92.0	14,000	14,000
					PX Brine cross flow =		549	gpm	
PX-70		QTY	**4**		Temperature = 25ºC				
PX UNIT FLOW		GPM	200		Flux ~ 13 gfd				
PX Internal Bypass		GPM	24						
Membrane Differential		PSI	10						
RO Recovery		%	65%						
System Recovery		%	85%						
HIGH PRESS. PUMP									
Feed Pump eff		%	90%						
Motor eff		%	93%						
VFD eff		%	97%		Total RO Process (kW)			189.1	
Power		kW	176.2						
BOOSTER PUMP					kWh/m3 Permeate			0.55	
Boost Pump Eff		%	60%		kWh/1000 gal Permeate			2.10	
Motor Eff		%	90%		kWh/acre-ft Permeate			684	
VFD eff		%	97%						
Power		kW	12.9						
Supply/Feed Pump kW			0.0						

Mechanisms associated with this novel mode of operation that might lead to improved performance at higher recoveries include:

- Improved boundary layer conditions by maintaining "high" velocities/flow

- Balanced membrane flux through increased lead element velocities
- Balanced membrane flux through increased lead element salinity
- Minimum brine flow requirements within manufacturers specifications
- Maximum allowable recoveries within manufacturers specifications

Testing this brine recirculation process is straight forward and will be achieved with the ADC Demonstration system in its Optimized Isobaric Energy Recovery Configuration as shown in Figure 2-2 and the detailed P&ID in Appendix A.

2.1.2.1 - Procedure for testing Brine Recirculation Process

Demonstration scale tests of the unbalance PX system will occur over an approximate 6 month period. As presented in Table 2-5, each phase of testing consists of the following:

- Two weeks (weeks 1-2) of "ripening" at a typical flux and recovery rate. This "ripening" period has been included based upon past experience operating new membranes. Experience has indicated that approximately two and one half weeks are required before some new membrane's performance (e.g., pressure and salt rejection) reaches a steady state condition. It is possible that pre-ripened membranes will be used in this test and this period may be shortened or omitted accordingly.
- Four weeks (weeks 3-6) of testing at different system and RO recovery points. Each recovery point will be operated for 1 day. The flux rates will be maintained at a constant 14.9 gallons per square foot of membrane area per day (gfd).
- 2 month demonstration at a single flux and recovery point

As indicated in Tables 2.6, two separate recovery rates will need to be determined and set for this test. These are the RO membrane recovery, which is determined by the PX booster pump flow and the total system recovery, which is determined by the PX LP inlet flow. The applicable equations are as follows:

RO R = $Q_{P\text{-}SYS}$ / $Q_{RO\ feed\ flow}$

System $R = \frac{Q_{P-SYS}}{Q_{F-SYS}} * 100$ **Equation 2.4**

$Q_{F-SYS} = Q_{P-SYS} + Q_{REJECT}$ **Equation 2.5**

$Q_{PXPump} = Q_{REJECT} + 1.5 gpm\_leakage$ **Equation 2.6**

$Q_{P-SYS} = Q_{F-HPPump} - 1.5 gpm\_leakage$ **Equation 2.7**

Where: R = Recovery, %

$Q_{F\text{-}SYS}$ = RO system feed flow, gpm

$Q_{RO\text{-}feed\text{-}flow} = Q_{PX\text{-}HP\text{-}out} + Q_{F\text{-}HP\text{-}Pump}$
$Q_{F\text{-}HP\ Pump}$ = High pressure positive displacement pump flow, gpm
$Q_{PX\text{-}HP\text{-}out}$ = PX High Pressure Outlet, gpm
Q_{Reject} = RO membrane reject flow, gpm

Between each system recovery matrix, the original/ripening flux and recovery (i.e., the flux and recovery tested during weeks 1-2) will be retested to confirm membrane performance at baseline conditions.

Approximately 8 weeks of operating at the RO-System recovery point determined, ***through testing***, to 1) meet water quality goals for TDS and 2) results in the most affordable operation, as determined by a net present value analysis or 3) an operating point that best matches the current operating conditions of full scale El Paso plant.

The data gathered from these tests shall be used to develop graphs that show the power consumption rate and water quality that can be achieved at each condition. Power consumption rate shall be measured to include the following electrical loads:

- High Pressure RO Pump (P2)
- PX Booster Pump (P3)

The following will not be included in the power consumption rate measurements

- Intake Lift Pump (P1)
- Chemical Metering Pumps
- Instrumentation and Controls
- Product water pumping
- Pretreatment pumping

While the intake lift pump may provide suction side pressure to the High Pressure Positive Displacement pump, thereby reducing the overall TDH, it will not be included in the power monitoring. For the affordability analysis, an intake pump’s horsepower will be assumed based upon flow and a overall lift TDH of 200 ft of H_2O.

Table 2.5 **Schedule of Testing Conditions**
Brine Recirculation Process for Higher Recovery in two Stage Array
ADC TWDB Desalination Demonstration Project

Parameter	**1-2 Weeks Ripening**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**
Membrane sq-ft	400						Base Line			
Flux, gfd	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9
RO recovery	80.0%	75.0%	75.0%	75.0%	75.0%	75.0%	80.0%	80.0%	80.0%	80.0%
System Recovery	80.0%	75.0%	80.0%	85.0%	90.0%	95.0%	80.0%	80.0%	85.0%	90.0%
High Pressure RO Pump ($Q_{F\text{-}HP\ Pump}$), gpm	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4
PX HP Outlet, ($Q_{PX\text{-}HP\text{-}Out}$), gpm	20.2	27.5	27.5	27.5	27.5	27.5	20.2	20.2	20.2	20.2
Permeate ($Q_{P\text{-}SYS}$), gpm	86.9	86.9	86.9	86.9	86.9	86.9	86.9	86.9	86.9	86.9
PX Low Pressure Inlet, gpm	20.2	27.5	20.2	13.8	8.2	3.1	20.2	20.2	13.8	8.2
Concentrate, gpm	21.7	29.0	21.7	15.3	9.7	4.6	21.7	21.7	15.3	9.7

-	**Day 10**	**Day 11**	**Day 12**	**Day 13**	**Day 14**	**Day 15**	**Day 16**	**Day 17**	**Day 18**	**2 Month Demo Point**
		Base Line				Base Line			Base Line	
Flux, gfd	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	TBD
RO recovery	80.0%	80.0%	85.0%	85.0%	85.0%	80.0%	90.0%	95.0%	80.0%	TBD
System Recovery	95.0%	80.0%	85.0%	90.0%	95.0%	80.0%	90.0%	90.0%	80.0%	TBD
High Pressure RO Pump ($Q_{F\text{-}HP\ Pump}$), gpm	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	TBD
PX HP Outlet, ($Q_{PX\text{-}HP\text{-}Out}$), gpm	20.2	20.2	13.8	13.8	13.8	20.2	8.2	3.1	20.2	TBD
Permeate ($Q_{P\text{-}SYS}$), gpm	86.9	86.9	86.9	86.9	86.9	86.9	86.9	86.9	86.9	TBD
PX Low Pressure Inlet, gpm	3.1	20.2	13.8	8.2	3.1	20.2	8.2	8.2	20.2	TBD
Concentrate, gpm	4.6	21.7	15.3	9.7	4.6	21.7	9.7	9.7	21.7	TBD

Notes:
1. Maximum system pressure is 600 psi. If any point exceeds 600 psi system will shutdown and point will need to be skipped.
2. Flows assume 400 sq-ft membrane
3. $Q_{F\text{-}HP\ Pump}$ = High pressure positive displacement pump flow = Product flow +1.5 gpm (PX leakage).
4. $Q_{PX\text{-}HP\text{-}Out}$ = PX booster pump flow= Concentrate flow gpm - 1.5 gpm (PX leakage).
5. $Q_{P\text{-}SYS}$ = SWRO system permeate flow.

2.2 Testing Operation and Monitoring

Hydraulic and water quality data will be collected to evaluate the operation of the demonstration scale equipment relative to the project goals for power consumption and treated water quality. These data shall be collected and evaluated by Carollo Engineers, P.C.

Tables 2.6-2.7 presents a matrix for monitoring hydraulic data from the demonstration scale brackish water RO equipment. Hydraulic data collected from this equipment consists of both pressure and flow data. The frequency of monitoring for each type of data is presented based upon the type/phase of operation. In general, data shall be collected once daily or at each individual flux and recovery during the 18 point data matrixes and 3 times per week during the 2 month demonstration phases. When applicable, flow meter calibration shall be checked at least weekly using a graduated bucket and a stop watch.

Hydraulic data shall be recorded in the data spreadsheet presented in Appendix B. The data spreadsheet shall be emailed weekly (i.e., Friday) to Carollo Engineers, P.C. Bradley Sessions (bsessions@carollo.com) and the ADC's, P.C. John MacHarg (johnmacharg@gmail.com) for data evaluation.

Water quality data shall be collected at the locations and frequencies presented in Tables 2.7 and analyzed by the methods presented in Table 2.8. These data shall then be recorded in the the spreadsheet in Appendix B. The data spreadsheet shall be emailed weekly (i.e., Friday) to Carollo Engineers, P.C. Bradley Sessions (bsessions@carollo.com) and the ADC's, P.C. John MacHarg (johnmacharg@gmail.com). One sampling for TOC, iron, manganese, and aluminum from location SC-1 every nine weeks will also be provided.

Table 2.6 Hydraulic Monitoring – Brackish water RO System
ADC TWDB Desalination Demonstration Project

Parameter	Unit	Each Flux/recovery point	Demonstration and Ripening Periods					Data Logger
			Monday	Tuesday	Wednesday	Thursday	Friday	
Pressure								
$P_{MF\text{-}in}$ (PI1)	psig	1x	1x	-	1x	-	1x	
$P_{MF\text{-}out}$ / $P_{CF\text{-}in}$ (PI1)	psig	1x	1x	-	1x	-	1x	
$P_{CF\text{-}out}$ (PI1)	psig	1x	1x	-	1x	-	1x	
$P_{PX\text{-}HP\text{-}out}$ (PI2)	psig	1x	1x	-	1x	-	1x	PT1
$P_{Stage1\text{-}out}$ (PI4)	psig	1x	1x	-	1x	-	1x	PT2
$P_{Stage2\text{-}In}$ (PI4)	psig	1x	1x	-	1x	-	1x	PT2
$P_{Stage2\text{-}out}$ (PI2)	psig	1x	1x	-	1x	-	1x	PT2
$P_{P\text{-}SYS}$ (PI3)	psig	1x	1x	-	1x	-	1x	
Flow								
$Q_{F\text{-}HP\ Pump}$ (FI3)	gpm	1x	1x	-	1x	-	1x	
$Q_{PX\text{-}LP\text{-}IN}$ (FI2)	gpm	1x	1x	-	1x	-	1x	FT2
$Q_{PX\text{-}HP\text{-}Out}$ (FI5)	gpm	1x	1x	-	1x	-	1x	FT5
$Q_{P\text{-}stage1}$ (FI6)	gpm	1x	1x	-	1x	-	1x	FT4
$Q_{P\text{-}stage2}$ (FI7)	kWh	1x	1x	-	1x	-	1x	AM1
$Q_{P\text{-}SYS}$ (FI4)	kWh	1x	1x	-	1x	-	1x	AM1
Power Consumption	kWh	1x	1x	-	1x	-	1x	AM1

Table 2.6 Hydraulic Monitoring – Brackish water RO System
ADC TWDB Desalination Demonstration Project

Parameter	Unit	Each Flux/recovery point	Demonstration and Ripening Periods					Data Logger
			Monday	Tuesday	Wednesday	Thursday	Friday	

Notes:
1. $P_{MF\text{-}in}$ = Pressure on the influent side of the media filters (PI1a)
2. $P_{MF\text{-}out}$ / $P_{CF\text{-}in}$ = Pressure on the effluent side of the media filters / Pressure on the inlet side of the cartridge filters (PI1b)
3. $P_{CF\text{-}out}$ = Pressure on the effluent side of the cartridge filters (PI1c)
4. $P_{PX\text{-}HP\text{-}out}$ = Feed water pressure at the PX high pressure outlet and inlet to Stage 1 membranes (PI2).
5. $P_{Stage1\text{-}out}$ = Stage 1 outlet pressure and PX booster pump inlet pressure (PI2)
6. $P_{Stage2\text{-}in}$ = Stage 2 inlet pressure and PX booster pump outlet pressure (PI2)
7. $P_{Stage2\text{-}out}$ = Stage 2 outlet pressure (PI2)
8. $P_{PX\text{-}LP\text{-}out}$ = Discharge pressure at the PX low pressure outlet, before the system recovery control valve (PI3b)
9. $P_{P\text{-}SYS}$ = RO system permeate pressure
10. $Q_{F\text{-}HP\ Pump}$ = High pressure positive displacement pump flow (FI3)
11. $Q_{PX\text{-}LP\text{-}IN}$ = Low pressure flow into the PX (FI2)
12. $Q_{PX\text{-}HP\text{-}Out}$= High pressure flow out of PX (FI5)
13. $Q_{P\text{-}Stage1}$ = Product flow from stage 1 array
14. $Q_{P\text{-}Stage2}$ = Product flow from stage 2 array
15. $Q_{P\text{-}SYS}$ = RO system permeate flow (FI4)
16. Power consumption will be calculated based on hydraulic data collected. On line measurements are taken from the Amp Meter.
17. Facility monitoring during weeks 3-6 will be required once per day.

Table 2.7 Water Quality Monitoring Brackish Water RO System
ADC TWDB Desalination Demonstration Project

		Each Flux and Recovery Point		Demonstration and Ripening Periods										Data Logger
				Monday		Tuesday		Wednesday		Thursday		Friday		
Parameter	**Unit**	**Location**	**No. of Times**	**Location**	**No. of Times**	**Location**	**No. of Times**	**Location**	**No. of Times**	**Location**	**No. of Times**	**Location**	**No. of Times**	
Temperature	^{o}C (^{o}F)	SC5, SC6, SC11	1x	SC5, SC6, SC11	1x	-	-	SC5, SC6, SC11	1x	-	-	SC5, SC6, SC11	1x	
pH		SC3, SC4, SC5, SC6, SC7, SC11	1x	SC3, SC4, SC5, SC6, SC7, SC11	1x	-	-	SC3, SC4, SC5, SC6, SC7, SC11	1x	-	-	SC3, SC4, SC5, SC6, SC7, SC11	1x	
Conductivity	mS/cm	SC3, SC5, SC6, SC7, SC11, SC12, SC13	1x	SC3, SC5, SC6, SC7, SC11, SC12, SC13	1x	-	-	SC3, SC5, SC6, SC7, SC11, SC12, SC13	1x	-	-	SC3, SC5, SC6, SC7, SC11, SC12, SC13	1x	
Total Dissolved Solids	mg/L	SC3, SC5, SC6, SC7, SC11, SC12, SC13	1x	SC3, SC5, SC6, SC7, SC11, SC12, SC13	1x	-	-	SC3, SC5, SC6, SC7, SC11, SC12, SC13	1x	-	-	SC3, SC5, SC6, SC7, SC11, SC12, SC13	1x	
Turbidity	NTU	Meter	1x	Meter	1x	-	-	Meter	1x	-	-	Meter	1x	NTU1
Silt Density Index		SC3	1x	SC3	1x	-	-	SC3	1x	-	-	SC3	1x	

Notes:
1. NS = No Sample
2. NA = Not applicable (e.g., value calculated)
3. Sample connection numbers per Harn P&ID revision 2, 4-19-05.

Table 2.8 Water Quality Testing Methods
Brackish water RO Demonstration Study
Affordable Desalination Collaboration

Parameter	Method	
	Seawater	RO Permeate
Temperature, ^{o}C	SM 2550	N/A
pH	SM 4500-H^+	SM 4500-H^+
Conductivity, $\mu S/cm$	SM 2510	SM 2510
TDS, mg/L	SM 2540C	SM 2540C
Turbidity, NTU	SM 2130	N/A
Silt Density Index	ASTM D4189-95	N/A
Boron, mg/L	EPA 200.7	EPA 200.7
Bromide, mg/L	EPA 300.0	EPA 300.0
Total Organic Carbon, mg/L	SM 5310C	SM 5310C
Iron, mg/L	EPA 200.7	EPA 200.7
Manganese, mg/L	EPA 200.7	EPA 200.7
Aluminum, mg/L	EPA 200.7	EPA 200.7
Calcium, mg/L	EPA 200.7	EPA 200.7
Magnesium, mg/L	EPA 200.7	EPA 200.7
Sodium, mg/L	EPA 200.7	EPA 200.7
Potassium, mg/L	EPA 200.7	EPA 200.7
Alkalinity, mg/L as $CaCO_3$	SM 2320B/EPA 310.1	SM 2320B/EPA 310.1
Carbon Dioxide, mg/L	SM4500-CO2-D	SM4500-CO2-D
Carbonate, mg/L	SM 2320B/EPA 310.1	SM 2320B/EPA 310.1
Bicarbonate, mg/L	SM 2320B/EPA 310.1	SM 2320B/EPA 310.1
Sulfate, mg/L	EPA 300.0	EPA 300.0
Chloride, mg/L	EPA 300	EPA 300.0
Fluoride, mg/L	SM4500F-C	SM4500F-C/EPA 300.0

Notes:
SM = *Standard Methods* for the Examination of Water and Wastewater, 20th Edition
ASTM = American Society for Testing and Materials
N/A = Not applicable

Water quality samples requiring analysis by a local, outside lab shall be shipped to a certified testing laboratory (to be determined).

Samples should be collected in a 125 ml polypropylene bottle, filled to the top with no head space. Preserve samples in accordance with the standards reference in Table 2.16, bubble rapped and shipped in a cooler overnight to the address above. Label sample bottles using a permanent marker with the:

- Location they were collected (e.g., “Raw”, “Feed”, “Permeate”, “PX Booster Pump Discharge”),
- Date collected
- Return authorization number (RA #) provided by lab.

Standard laboratory quality assurance and quality control procedures shall be practiced. Laboratory instruments shall be calibrated in a manner consistent with the Standard or EPA method procedure. Duplicate and blank samples shall be analyzed as required by the testing method. On-line instruments shall be calibrated as recommended by the instrument manufacturer’s specifications.

2.3 Membrane Cleaning & Storage

2.3.1 RO Membranes

Membrane cleaning will be performed if bench-mark testing (i.e., conducted between test during weeks 3-5) indicates a higher differential pressure across the RO system when compared to the initial (Weeks1 through 3) test performance. Membrane cleaning procedures will be per the recommendations of the respective membrane supplier. A summary of cleaning procedures provided by each membrane supplier is provided in Appendix C.

The ADC may conduct more testing at other sites in the future. Membranes shall be stored to ensure that they will be able to perform for these future studies. The following procedures shall be followed for membrane storage:

- Unless the elements have experienced significant performance decline it should not be necessary to clean the elements prior to storage. However, elements will be flushed with stored permeate (in the CIP/suck back tank) until a TDS less than 800 mg/L is recorded from sample location SC5 (Refer to Appendix B).
- If enough stored permeate remains, the CIP tank will be used to flush the membrane elements with a 1 to 1.5% bisulfite solution. If there is not enough stored permeate remaining, upon removal from the pressure vessels, the elements should be drained of excess water by standing on end after removal from the pressure vessel. The elements should then be submerged in a small tank or barrel of 1 to 1.5% sodium bisulfite/permeate solution for a minimum of 1 hour. Distribution of the preservative solution is enhanced if the element is lifted, drained, and re-submerged 2-3 times during the soak time.

- The elements will arrive sealed in oxygen barrier bags that can be reused to store the elements. As much excess air as possible should be removed from the bag prior to sealing it with tape. If possible, bags should be vacuum-sealed.
- For optimal storage conditions the bagged elements should be stored out of direct sunlight at a temperature <25°C.
- For long-term storage, 2 elements should be opened and the pH determined of the residual preservative solution every 2-3 months. If the pH drops below 3, the elements should be re-preserved.

2.4 Determining Affordability

After completion of the variable flux and recovery tests, a present value analysis will be conducted to establish the most affordable operating condition, which accounts for both capital and operations costs.

The criteria presented in Table 2-9 shall be the basis for the present value analysis.

Table 2-9 Present Value Analysis Criteria
Brackish Water RO Demonstration Study
Affordable Desalination Collaboration

Criteria		Value
Project Size		25 MGD
Capital Cost		
	Pretreatment	Media followed by cartridge
	Desalination Plant	To be developed using WTCOST based upon demonstration test condition
Project Life		20 years
Bond Payment Period		20 years
Interest		3.5%
Inflation		3%
Construction Contingencies		15% of capital cost
Contractor OH&P		10% of capital cost
Engineering & Const. Mgmt.		25% of capital cost
Annual Maintenance Costs		1.5% of the capital cost
Power Cost		$0.12 per kWhr
Intake Lift Pump TDH		200 ft H_2O
High Service Pump TDH		200 ft H_2O
Intake/High Service Pump Efficiency		TBD
Intake/High Service Lift Pump Motor Efficiency		TBD

Table 2-9 Present Value Analysis Criteria
Brackish Water RO Demonstration Study
Affordable Desalination Collaboration

Criteria	Value
Membrane Life	5 years
Membrane Element Cost	TBD
No. of Plant Staff and Salary	TBD
Labor overhead multiplier	x 1.75
Cartridge Filter Loading Rate	3 gpm per 10-inches
Cartridge Filter Cost	$3 per 10-inches
Cartridge Filter Life	Determined during demonstration test
Carbon Dioxide Dose	16 mg/L
Carbon Dioxide Cost	$0.04 per pound
Lime Dose	44 mg/L
Lime Cost	$0.05 per pound
Sodium Hypochlorite Dose (post treatment)	1.5 mg/L

NOTES:
1. Includes costs for RO equipment, CIP equipment, building, process electrical and instrumentation, yard piping, post treatment chemical facilities, 5-MG of ground storage and high service pumping.
3. Inflation based upon historic ENR cost index inflation over 50 years. Inflation will be applied annually.
4. Assumes no chlorine demand. 4.6 mg/L of SBS will quench 2 mg/L of Cl_2.

Appendix A

PROCESS AND INSTRUMENTATION DIAGRAMS

REV	DESCRIPTION	DATE	APPROVED
1	INITIAL RELEASE	5-1-09	

REVISIONS

P1 SUPPLY PUMP
QTY: 1
FLOW: 70-170 GPM
PRESSURE: 30 PSI MIN.
POWER: 460VAC/60/3PHASE
MOTOR: 10 HP

P2 HP PUMP
QTY: 1
FLOW: 35-90GPM
PRESSURE: 100-1140 PSI
POWER: 460VAC/60/3PHASE
MOTOR: 50 HP

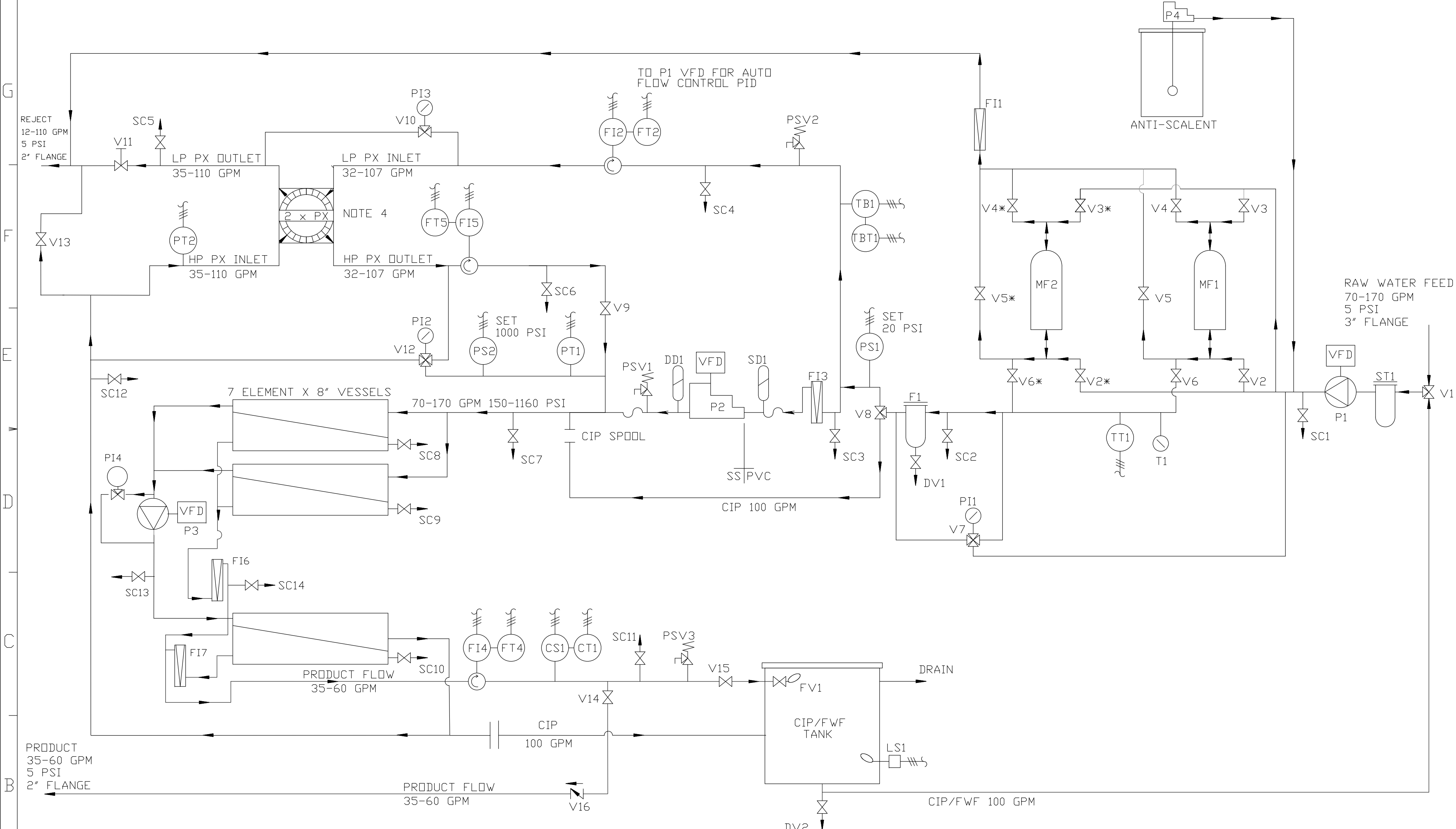
P3 HP PUMP
QTY: 1
30-110 GPM
PRESSURE: 30-50 DELTA PSI
POWER: 460VAC/60/3PHASE
MOTOR: 5 HP

P4 CHEMICAL INJ PUMP
QTY: 1
TBD
PRESSURE: 100 PSI
POWER: 110VAC/60/1PHASE
MOTOR: TBD

MF1/MF2 MEDIA FILTER
QTY: 2
OPERATION: MANUAL
DIA x HIGH: 36" x 72"
M.O.C.: GRP

CARTRIDGE FILTER
QTY: 1
CAPACITY: 200 GPM
M.O.C.: GRP
MFGR: EXCEL

RO VESSELS
QTY: 3
TYPE: 8" X 7 ELEMENT
ARRAY: 2-1



NOTES:

1. MAIN HP PUMP AND PRODUCT FLOW RATE WILL BE ADJUSTABLE USING A VFD DRIVE TO CONTROL THE MAIN HP PUMP. APPROX. HP PUMP FLOW RANGE WILL BE 80-90 GPM.
2. FRESH WATER FLUSH (FWF) IS REQUIRED TO KEEP PRESSURE EXCHANGER AND MEMBRANES FREE OF BIOLOGICAL GROWTH DURING SHUTDOWN. SEE START AND STOP PROCEDURES IN O&M MANUAL.
3. CIP CONNECTION ARE TWO BLIND FLANGES WITH A REMOVABLE PIPE SPOOL.
4. PX MANIFOLD WILL HOLD 2EA, PX-UNITS.

SYSTEM FLOW PARAMETERS (GPM)

	% REC	GFD	FEED	PERM	REJECT
MIN FLOW	85	12	82	70	12
MAX FLOW	75	16	124	93	31
DESIGN FLOW	85	149	102	87	15

1	SH	REVISION STATUS
-	REV	OF SHEETS

CAGE NO. N/A DWG NO. AKB-5109-12 SH 1 REV 1

ADC
2419 E. Harbor Blvd, Ventura, CA 93001

ADC PILOT PLANT
P&ID DIAGRAM

DRAWN A. BENNETT DATE 5-1-09
CHECKED DATE
APPROVED DATE
ISSUE DATE
CONTRACT NO.

? NEXT HIGHER ASSEMBLY
APPLICATION

SIZE E CAGE NO N/A DWG NO AKB-5109-12 REV 1
SCALE N/A SHEET 1